Cost-Effective Compliance with Life Safety Codes

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Abstract

ALARM is personal computer software that helps building managers and fire safety engineers achieve cost-effective compliance with the widely used NFPA 101, *Life Safety Code®*. The software currently supports health-care occupancy analysis. Through the equivalency provision of the code, *ALARM* implements a goal-oriented, or performance-based, approach to code compliance. The software generates a set of alternative code compliance strategies and their estimated construction costs. Engineering judgment is then applied to select the most appropriate code compliance strategy based on both cost and design considerations. The software offers a code-compliance optimizer, a comprehensive file manager, and a full-screen data editor. Since 1981, the optimization method used in *ALARM* has been field-tested in 89 hospitals (17,898 beds). For this sample, the least-cost solution identified by the software was, on average, 41 percent less expensive than the prescriptive solution. This represents a potential cost savings of $2,116 per bed or more than $37 million. Future versions of *ALARM* could address other building occupancies.

Introduction

This paper describes new software called *ALARM*, which is designed to help fire safety engineers and building managers at health care facilities achieve cost-effective fire code compliance. *ALARM*, which stands for Alternative Life Safety Analysis for Retrofit Cost Minimization, was developed at the National Institute of Standards and Technology's Building and Fire Research Laboratory in cooperation with the U. S. Public Health Service (USPHS).[1] The software generates a set of alternative compliance strategies and their estimated construction costs for meeting the current edition of NFPA 101, *Life Safety Code®* (*LSC*).[2] The *LSC*, a voluntary code, is widely used to identify the minimum level of building fire safety. *LSC* compliance is a condition for accreditation by the Joint Commission on Accreditation of Health Care Organizations.

Primarily, the *LSC* is prescriptive, since it requires specific solutions for fire safety. For example, it might require both a minimum flame-spread rating for interior finishes and a manual fire alarm system. However, a provision allows for

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alternative code compliance through a goal-oriented, or performance-based, fire safety code. By using an equivalency concept, performance-based codes determine how fire safety parameter combinations can achieve a fire safety level equivalent to that required by prescriptive codes.

Background

Health care occupancies were the first buildings covered by a formal equivalency system, which was originally developed in the late 1970s at NIST, then called the National Bureau of Standards.[3] In 1981, NFPA adopted this equivalency system into the *Life Safety Code*.[4] This equivalency method, known as the fire safety evaluation system (FSES), has been modified and updated several times since then. The current edition is published as NFPA 101A, *Alternative Approaches to Life Safety*, and includes FSESs for business, board-and-care, and correctional occupancies.[5] Currently, *ALARM* supports only the 1995 edition of the FSES for health-care occupancies.

NFPA 101A requires analysis and scoring of each of a building's zones—a space that is separated by floors, horizontal exits, or smoke barriers. The analysis looks at 13 fire safety parameters with up to 7 safety levels for each, for a total of 56 parameters. Zones earn points for each safety parameter based on its impact on each of the four fire safety categories. Points earned in a zone's 13 parameters are then compared with the mandatory point requirements for the four fire safety categories: containment, extinguishment, people movement, and general safety. If the point totals meet or exceed all four requirements, according to NFPA 101A, the zone has achieved fire safety equal to the prescriptive code. Every zone must achieve this equivalency through the point system. For full code compliance, the building as a whole must also meet the facility fire safety requirements specified in Table 3-8 of NFPA 101A.

Construction Cost Minimization Method

Since the mandatory point requirements are established for total scores across all fire safety parameters only, tradeoffs among the 13 parameters are possible. For example, in exchange for more widespread, automatic sprinklering, less smoke control may be allowed. These potential tradeoffs generate possible savings in fire code compliance. Less expensive fire safety parameters may be substituted for more expensive parameters, while maintaining an acceptable level of fire safety. With four independent mandatory point requirements, 13 fire safety parameters, each with up to seven fire safety levels, and many zones to analyze, the problem quickly becomes difficult to solve by manual computation and comparison. A cost-minimization method, implemented in a software tool, is needed.

A construction cost-minimization method for this kind of problem was originally developed by Chapman and Hall and applied to the 1981 edition of the FSES for health-care occupancies through the software, *Fire Safety Evaluation*

System Cost Minimizer (FSESCM).[6,7,8,9] The method applies linear programming, a mathematical technique, and efficiently evaluates all possible code-compliance solutions. The general idea is to balance improvements in fire safety scores with the construction costs necessary to achieve them, thus identifying the least-cost means of achieving code compliance.

Since the 1981 edition of the FSES for health-care occupancies was adopted, the FSESCM software has been extensively field tested. Important changes have been made in building fire safety technology, in construction costs, and in the FSES itself. Moreover, improved computer hardware and software development tools now support user-friendly, interactive software. In response, the optimization software, the construction cost-estimating algorithms, and the supporting data have all been updated. In addition, an interactive environment for the updated optimization software has been developed and integrated into *ALARM*. All of the construction cost algorithms and supporting data are thoroughly documented.

Data Requirements

ALARM's integrated file manager and full-screen data editor allow easy, quick, and reliable data entry. The file manager lists all building data files, which are created with the data editor and contain all data necessary to run the optimizer for an entire building. The software even includes a sample building file. The file manager is the command center from which the user can perform typical data file operations, such as copying, renaming, deleting, and printing, as well as the primary operations of entering building and zone data and running the optimizer.

The data editor is used to enter data on the hospital under study. The editor displays on-screen prompts and uses data validation routines to create error-free data files. To facilitate the data entry process, the manual has a data collection form that mirrors the data editor layout.

Data must be entered on the building as a whole, on each zone, and on each fire safety parameter in each zone. Building information includes general information, a building qualifier, construction cost modifiers, and a zone listing. General information includes the name and address of the building. The building qualifier indicates whether the building has sprinklers and whether it is new, in order to determine part of the four mandatory point requirements. The construction cost modifiers are used to adjust, by the same percentage, the automatic cost estimates for all retrofits, permitting time- and location-specific cost adjustments to all default unit costs.

Data needed for each zone include its name, identification number, floor number, and occupancy risk factors. The risk factors are used to determine the mandatory point score for general safety. They cover patient mobility, patient density, zone location, patient-to-attendant ratio, and average patient age.

Users must enter the current fire safety state of the zone and all the retrofit quantities needed to achieve a state that is safer than the current state for each of the 13 fire safety parameters. For some fire safety parameters, special design specifications may be entered to define a zone's fire safety status or potential retrofits further. For example, an automatic sprinkler specification parameter covers asbestos removal during sprinkler installation. Users may rule out any state to force the optimization procedure to ignore it. Using the retrofit quantities and special design specifications, the cost estimation algorithms compute the construction cost of moving from the current state to each available safer state. A cost adjustment, either positive or negative, may also be entered for each state to include costs for an unlisted retrofit or to reduce the automatic cost estimate.

Reports

Once the data on all the zones have been entered and saved in the file, the user selects the file manager's optimizer feature, which generates a report file with alternative code compliance options and estimated construction costs. Engineering judgment may be used to select the most appropriate compliance option based on both construction cost and design considerations. For benchmarking purposes, the optimizer also reports the prescriptive solution cost for each zone and for the building as a whole.

Table 1 shows the key FSES tables, zone reports, and building summary reports contained in the report file. The FSES tables are included for informational purposes.

There are three zone reports. The first shows the data input for occupancy risk factors, the current fire safety state, and the retrofit quantities for each fire safety feature. The prescriptive compliance state is also shown. The second report shows the total estimated retrofit costs of each fire safety state and of prescriptive compliance for the zone as a whole. And the third report lists all code-compliance strategies generated by the optimizer for the zone. Each strategy is identified by its solutions for the 13 fire safety parameters. The total construction cost for each strategy is also reported. Finally, this report gives the number of surplus points earned by each strategy in excess of the four mandatory point requirements. Fire safety engineers can use this information to judge the relative safety margin offered by each strategy.

The building summary reports match common compliance strategies across all zones in the building. Twenty default design classes, defining specific safety levels for some of the fire safety parameters, are built into the software. One default design class, for example, calls for automatic sprinklers throughout the entire building, a single deficiency in hazardous areas, no horizontal exits, and no changes in construction type, zone dimension, or smoke detection. The design class reports identify the least-cost compliance strategy that satisfies the design class specifications. The reports are sorted in order of total construction costs of compliance. If a zone cannot achieve code compliance under a given design class, that class is not reported. Each report provides a set of alternatives from

TABLE 1
Optimization Reports of *ALARM*

1. FSES tables
   1.1 occupancy risk parameter factors
   1.2 mandatory safety requirements
   1.3 safety parameter values
2. Zone reports
   2.1 data inputs
   2.2 estimated retrofit costs
   2.3 code-compliance strategies
3. Building summary reports
   3.1 design class reports (20)
   3.2 prescriptive solution report

which to select the most appropriate compliance strategy based on both cost and design considerations. If the default design classes do not satisfy design requirements for a facility, the user may select a customized set of solutions from the individual zone reports. The prescriptive solution report gives the cost of prescriptive compliance for the total building.

Conclusions and Future Directions

Since 1981, the *ALARM* approach has been field tested by the USPHS in many hospitals, and more than 300 copies of *ALARM* have been sold. Because the software estimates the construction costs of the low-cost, safety-equivalent solutions, as well as of the prescriptive solution, the potential cost savings from using the FSES with *ALARM* can be estimated. For the 89 hospitals (17,898 beds) surveyed by the USPHS, the least-cost solution identified by *ALARM* was on average 41 percent less expensive than the prescriptive solution specified in NFPA 101. This represents a potential cost savings of $2,116 per bed, or more than $37 million. In 1993, the software was applied to the largest hospital yet—the 60-zone, 62,710-square-meter (675,000-square-foot) Wright-Patterson Air Force Base hospital in Ohio. ALARM estimated the savings from using the least-cost alternative FSES solution at more than $500,000. The 40-bed hospital at Yokota Air Force Base in Fussa, Japan, was surveyed the same year, with savings from using the least-cost solution estimated at $136,000.

This first version of *ALARM*, designed with built-in flexibility for making future changes, will have to be revised when the FSES for health-care occupancies is significantly modified or when retrofit cost estimates become so outdated that across-the-board inflation adjustments are no longer realistic. A network version would permit many users to edit the same building data file simultaneously. On-site data entry through a laptop, and ultimately a pen-based version of the software, would improve productivity. Building data are currently developed in two stages: notes are made on building blueprints on site and then translated into data for entry into *ALARM.* A pen-based computing application could load digitized blueprints into a hand-held computer. Notes made on these digitized blueprints could automatically be converted into the necessary building data.

With the success of the FSES for health-care occupancies, equivalency systems were developed for business, board-and-care, and detention and correctional occupancies. The *ALARM* methodology for reducing code-compliance costs is equally applicable to these and other occupancies as more FSES systems are developed. Software tools tailored to these occupancies could be developed in the future.

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